National Aeronautics and Space Administration

International Space Cooperation and Inter-Agency Partnerships

NASA Advisory Council Briefing

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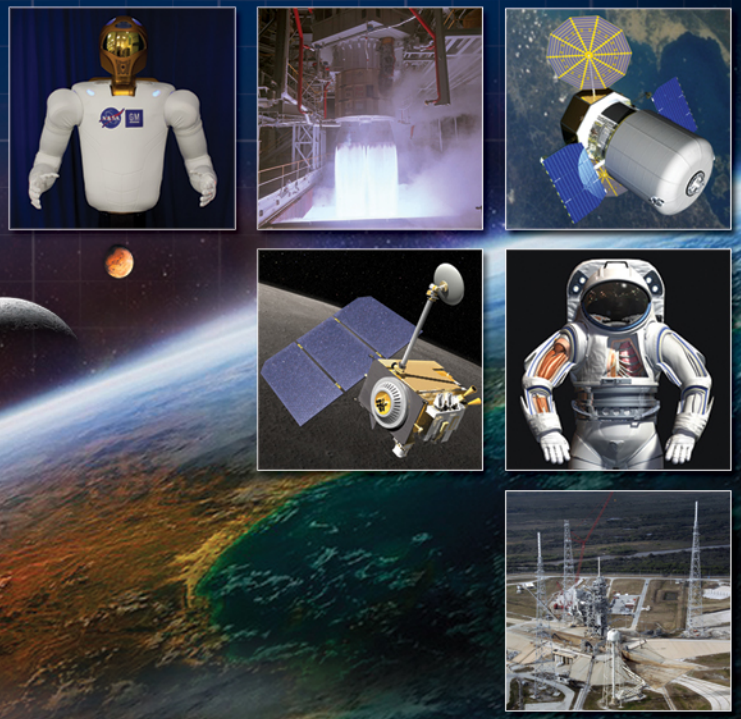
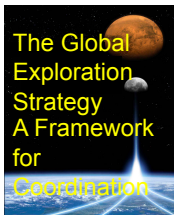
21 Sept 2010



NASA Partnerships: Enabling Exploration

- **International Activities**
  - Global Exploration Strategy (GES)
  - International Space Exploration Coordination Group (ISECG)
    - 14 Int'l Space Agencies
  - Developing the Global Exploration Roadmap
  - Bilateral dialogue robotics, analog, ISS utilization, etc
  - Strong international participation in analog field tests
- **Other Government Agencies (OGAs)**
  - Leveraging other government programs and technologies to minimize costs & maximize efficiency and innovation (e.g. DoD, DOE, DARPA, NOAA, NSF, DoC)
- **Science and Academia**
  - Seeking to maximize synergy between Human Robotic Missions
  - Human Research Program
  - Coordinating with internal, external groups

  (e,g. NLSI, LSI, LEAG)
- **Commercial: Traditional & Non-traditional**
  - Strong NASA interest in enabling commercial opportunities that contribute to exploration program success



May 2007

International Partnerships Strategy

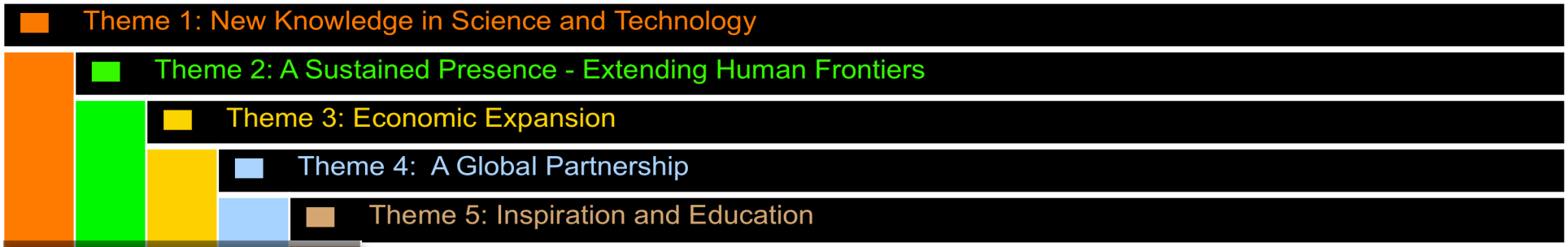
- **NASA leadership of a sustainable and affordable human space exploration of many destinations is enabled by, and may require, critical international partnerships (IPs)**
- **Purpose:**
  1. Reduce costs (not LCC) or obtain funding or resource offsets
  2. Enhance sustainability thru interdependent alliances, vital contributions, joint/cooperative ventures, and potential critical path dependencies or key contributions
- **Build from HEFT – Engage Near-term with IPs for a long-term coordinated vision:**
  - Engaging IPs in both bi-lateral and multi-lateral discussions
  - Communicating human and robotic mission plans/interests in a timely/transparent manner
  - Sharing US objectives, framework options/decisions, key capabilities list
  - Leveraging HEFT products for a global exploration roadmap
  - Shaping technology development, demonstration and precursor investments
  - Fully utilizing ISS to demonstrate technologies, advanced capabilities, & expanded partnerships
  - Creating opportunities for new partnerships once timing/environment is “right”
- **NASA leadership is considered essential to advance the global exploration strategy**
  - Continue to engage via the International Space Exploration Coordination Group (ISECG) and ISS Multilateral Coordination Board (MCB)
  - HEFT is important to inform and frame the path forward

The First Step: Common Goals & Strategies

- **Common Goals for Human Lunar Exploration**
  - Derived from individual agency objectives
  - Independent of architecture; precede its development
  - Could drive multiple architectural approaches
  - Used to evaluate the reference architecture approach
  - Cross-cutting and compelling; linked to GES themes
- **Strategic Guidance**
  - Derived from relevant strategic interests of participating agencies
  - Guided the reference architecture approach

Strategic Guidance

- Advance the principles of programmatic and technical sustainability and ensure their early incorporation in the architecture
  - Apply a phased approach to exploration with interim milestones to accommodate evolution of mission objectives and changes in programmatic priorities
  - Include a phase that captures robotic missions to the moon in preparation for human lunar surface operations
  - Consider affordability in laying out campaign approaches
  - Maximize the synergies between human and robotic activities
- Balance compelling science and Mars Forward objectives, understanding that specific Mars Forward and science priorities will evolve.
- Take due consideration of ISS Lessons Learned including the importance of dissimilar redundancy in critical systems.

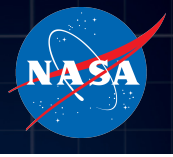


Common Goals for Human Lunar Exploration

(Traced to "GES: The Framework for Coordination")

1.	Embrace a long-term strategic view for enhancing and expanding global partnerships for sustainable exploration of the Moon and beyond.
2.	Maximize early international partnership opportunities for lunar exploration.
3.	Use lunar exploration as a stepping stone for the demonstration of technologies, operational concepts, and cooperation approaches for Mars and other destinations.
4.	Take maximum advantage of ISS assets and other opportunities in LEO to advance technologies and capabilities for exploration beyond LEO.
5.	Develop, demonstrate and apply innovative capabilities, technologies and processes for improving resource and energy management and environmental protection, driven by the challenge of sustaining human life and operations in the hostile environment of space and the lunar surface.
6.	Develop a flexible, robust and reliable architecture that allows humans to safely explore the moon.
7.	Stimulate economic development and industrial innovation to enhance global economic prosperity via exploration of the Moon.
8.	Understand the origin and evolution of the Moon
9.	Interpret the uniquely preserved record of solar system evolution on the Moon and its relation to the origin and evolution of life
10.	Extend human presence in the solar system and improve the health of humans on Earth, by understanding and mitigating the risks to astronaut health in the lunar environment.
11.	Maximize science return by leveraging human presence on the Moon and/or capabilities developed for lunar exploration
12.	Develop innovative tools, means and methods to enable the public to engage interactively in human exploration.
13.	Inspire the next generation to embrace the tools of exploration: science, technology, engineering, mathematics and a sense of curiosity.
14.	Engage the public on the broader rationale and benefits of exploration.
15.	Achieve early, frequent and inspiring milestones relevant to the partnership, and to the public.

ISECG Reference Architecture for Human Lunar Exploration



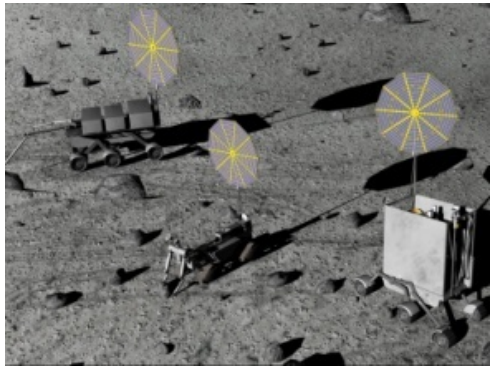
- **An international vision for a human lunar exploration architecture and concept of operations**
  - Demonstrates importance of early coordination on objectives, approaches, concepts
- **Developed to inform near term agency decision making**
  - Technology development and demonstration, including use of ISS
  - Interface standardization
  - Roles for exploration
  - Partnerships
- **Advanced many of the concepts of sustainability**
  - Robotic operations on lunar surface between crew visits
  - Reusable and re-locatable surface assets
  - Science objectives are equal in priority to Mars surface risk reduction objectives
  - Flexibility to accommodate changes in technologies, international partner priorities and programmatic constraints
  - ISS Lessons Learned, such as supply chain impacts
- **“Phase 0” level of definition**
  - Enables individual agency decision making
  - Enables interested agencies to build partnerships necessary to take this work to the next level
- **A global “point of departure” (gPOD) architecture which can facilitate coordinated preparatory activities of interested agencies within ISECG**
  - However, preparatory activities of all participants are heavily dictated by US Policy decisions

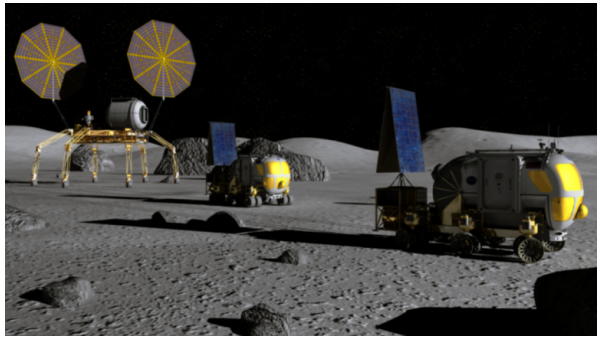
Phase Definitions

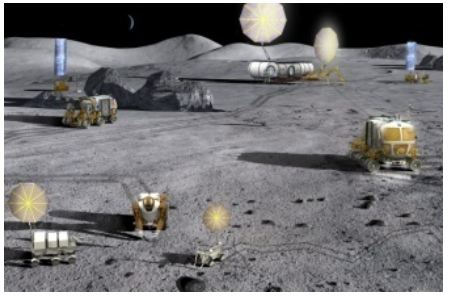
The architecture is organized into five distinct phases which can be implemented in any order:

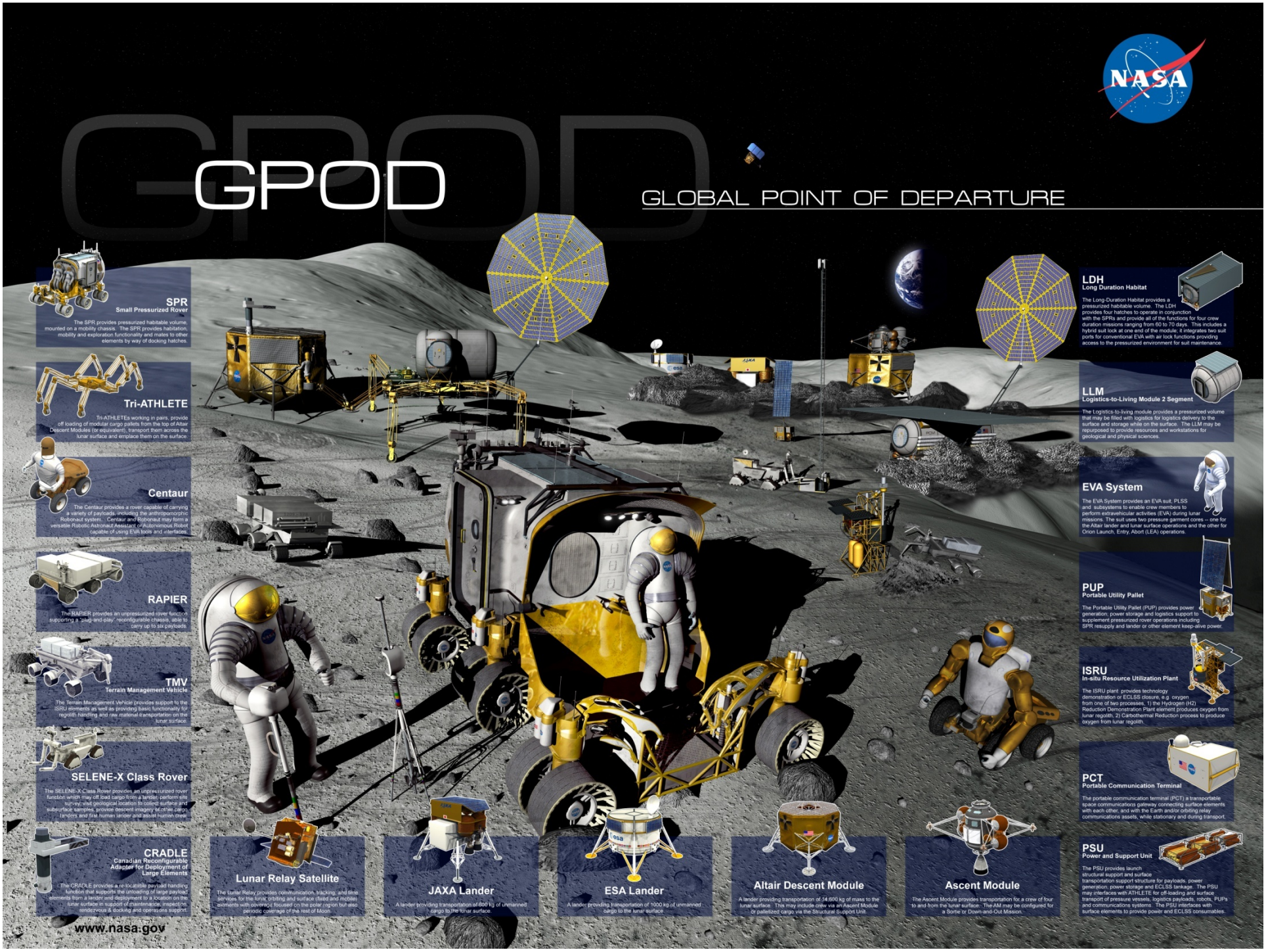
- **Early Robotic Phase** – Robotic missions to increase knowledge, and reduce risk
- **Polar Exploration / System Validation Phase** – Validation & verification of mobility and power infrastructure assets at the lunar pole
- **Polar Relocatability Phase** – Enable extended crew missions to “near polar locations” with mobile surface assets
- **Non-Polar Relocatability Phase** – Use of evolved assets to enable crew exploration, of at least 14 days, at non-polar locations
- **Long Duration Phase** – Enable extended crew expeditions of at least 60 days

Ability to add targeted Sortie missions to meet science objectives as required








GPOD
GLOBAL POINT OF DEPARTURE
SPR
Small Pressurized Rover
The SPR provides pressurized habitable volume, mounted on a mobility chassis. The SPR provides habitation, mobility and exploration functionality and mates to other elements by way of docking hatches.
Tri-ATHLETE
Tri-ATHLETEs working in pairs, provide off loading of modular cargo pallets from the top of Altair Descent Modules (or equivalent), transport them across the lunar surface and emplace them on the surface.
Centaur
The Centaur provides a rover capable of carrying a variety of payloads, including the anthropomorphic Robonaut system. Centaur and Robonaut may form a versatile Robotic Astronaut Assistant or Autonomous Robot capable of using EVA tools and interfaces.
RAPIER
The RAPIER provides an unpressurized rover function supporting a "plug-and-play" reconfigurable chassis, able to carry up to six payloads.
TMV
Terrain Management Vehicle
The Terrain Management Vehicle provides support to the ISRU elements as well as providing basic functionality for regolith handling and raw material transportation on the lunar surface.
SELENE-X Class Rover
The SELENE-X Class Rover provides an unpressurized rover function which may off load cargo from a lander, perform site survey, visit geological location to collect surface and subsurface samples, provide descent imagery of other cargo landers and first human lander and assist human crew.
CRADLE
Canadian Reconfigurable Adapter for Deployment of Large Elements
The CRADLE provides a re-locatable payload handling function that supports the unloading of large payload elements from a lander and deployment to a location on the lunar surface in support of maintenance, inspection, rendezvous & docking and operations support.
www.nasa.gov
LDH
Long Duration Habitat
The Long-Duration Habitat provides a pressurized habitable volume. The LDH provides four hatches to operate in conjunction with the SPRs and provide all of the functions for four crew duration missions ranging from 60 to 70 days. This includes a hybrid suit lock at one end of the module; it integrates two suit ports for conventional EVA with air lock functions providing access to the pressurized environment for suit maintenance.
LLM
Logistics-to-Living Module 2 Segment
The Logistics-to-living module provides a pressurized volume that may be filled with logistics for logistics delivery to the surface and storage while on the surface. The LLM may be repurposed to provide resources and workstations for geological and physical sciences.
EVA System
The EVA System provides an EVA suit, PLSS and subsystems to enable crew members to perform extravehicular activities (EVA) during lunar missions. The suit uses two pressure garment cores -- one for the Altair lander and lunar surface operations and the other for Orion Launch, Entry, Abort (LEA) operations.
PUP
Portable Utility Pallet
The Portable Utility Pallet (PUP) provides power generation, power storage and logistics support to supplement pressurized rover operations including SPR resupply and lander or other element keep-alive power.
ISRU
In-situ Resource Utilization Plant
The ISRU plant provides technology demonstration or ECLSS closure, e.g. oxygen from one of two processes; 1) the Hydrogen (H2) Reduction Demonstration Plant element produces oxygen from lunar regolith, 2) Carbothermal Reduction process to produce oxygen from lunar regolith.
PCT
Portable Communication Terminal
The portable communication terminal (PCT) a transportable space communications gateway connecting surface elements with each other, and with the Earth and/or orbiting relay communications assets, while stationary and during transport.
PSU
Power and Support Unit
The PSU provides launch structural support and surface transportation support structure for payloads, power generation, power storage and ECLSS tankage. The PSU may interfaces with ATHLETE for off-loading and surface transport of pressure vessels, logistics payloads, robots, PUPs and communications systems. The PSU interfaces with surface elements to provide power and ECLSS consumables.
Lunar Relay Satellite
The Lunar Relay provides communication, tracking, and time services for the lunar orbiting and surface (fixed and mobile) elements with coverage focused on the polar region but also periodic coverage of the rest of Moon.
JAXA Lander
A lander providing transportation of 600 kg of unmanned cargo to the lunar surface.
ESA Lander
A lander providing transportation of 1000 kg of unmanned cargo to the lunar surface.
Altair Descent Module
A lander providing transportation of 14,600 kg of mass to the lunar surface. This may include crew via an Ascent Module or palletized cargo via the Structural Support Unit.
Ascent Module
The Ascent Module provides transportation for a crew of four to and from the lunar surface. The AM may be configured for a Sortie or Down-and-Out Mission.

ISECG Current Status

- ISECG has demonstrated the ability to advance awareness and develop products which inform near term decisions of agencies

- ISECG is not a governance structure but a technical coordination forum
  - Producing products that allow individual agencies to make more informed decisions, understanding the international context

- ISECG is considered necessary but not sufficient to advance the GES
  - ISECG well suited for technical coordination
  - Political level dialog (what, when) also important

- June 2010: First meeting of ISECG "Head's of Human Spaceflight" Program
  - Universal recognition of the role ISECG can play in aligning agency plans and programs
  - Recognition that continued engagement at this level was needed to address strategic questions

- Next major face to face meeting, June 2011
  - Agree on Global Exploration Roadmap, Rev 1

ISECG Priorities for Coming Year

- The Global Exploration Roadmap
  - Rev 1 will be available in June 2011
    - Significant advancement of Visionfor content, development process
  - Two Global Exploration Roadmap products are envisioned
    - Overview of integrated firm agency plans for exploration, a product that becomes increasingly specific about next steps for humans beyond LEO as agency plans are solidified
    - Recommendations on the next steps for coordinated space exploration based on an assessment of agency's strategic considerations, future, not yet firm, plans/concepts, and develop consensus on key strategic factors
- Seeking ways to collaborate in advancing public and stakeholder engagement

ESMD Bilateral Partnership Summary

- Within the constraints of the US Policy situation, We are actively pursuing opportunities to partner to add
  - New knowledge of destinations like moon and NEO
  - Advance technologies tied to key exploration capabilities
  - Ensure ISS is fully utilized
- Terrestrial analog activity cooperation with CSA, DLR, ESA
- Technology development information exchanges with DLR, CNES, ESA, JAXA
- Regular bilateral dialog with partners
  - Technology demonstration cooperation
  - Robotic precursor cooperation

Other Government Agency (OGA) Partnerships

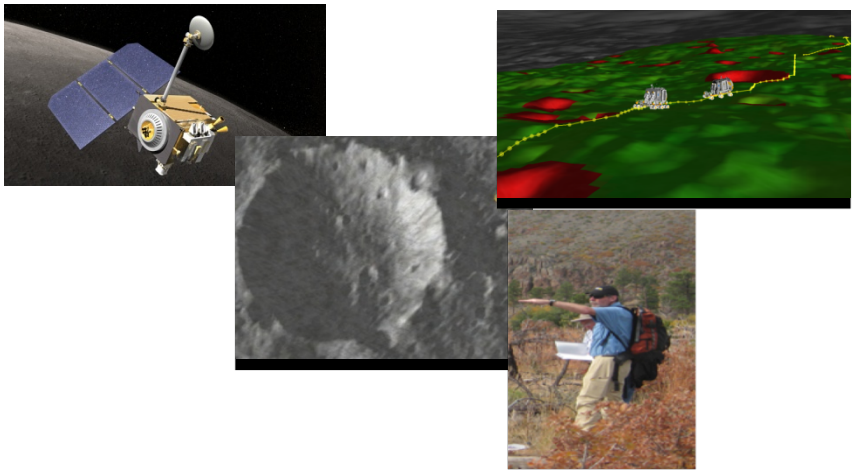
Vector: Collaboration & Engagement

- A major thrust of the Exploration Systems Mission Directorate is to Partner with Other Government Agencies to minimize costs and maximize efficiency and innovation of future human space exploration missions
  - Participate in inter-agency studies
  - Leverage other government agency's technology development programs
  - Utilize other government agency's capabilities (e.g. resources, facilities, infrastructure, etc)
  - Collaborate with other government agency experts (USGS, DOE nuclear)
  - Enhance affordability and sustainability

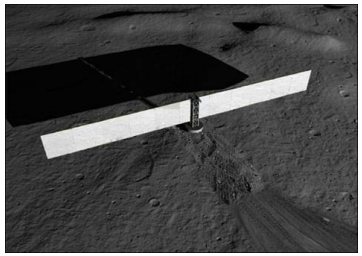
Collaborate with Other Government Agency Experts

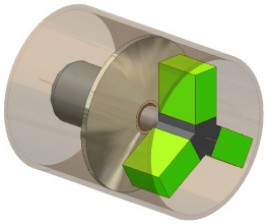
Examples

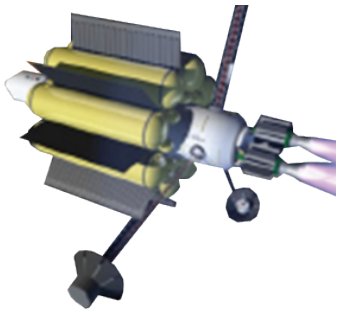
- **USGS Geological Science Expertise** - NASA Collaborates with USGS on:
  - Development of lunar maps including those developed from LRO data
  - Geological science operational concept development including the testing of concepts at NASA analog field tests



- **DOE Nuclear Energy Experts** - NASA Collaborates with DOE Nuclear experts on:
  - Development of surface fission power analysis and concept development
  - Development of in-space nuclear energy generation concepts and technologies
  - Development of surface and in-space utilization of Radioisotope Power Systems (RPS) analysis and concept development

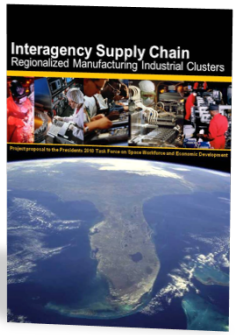


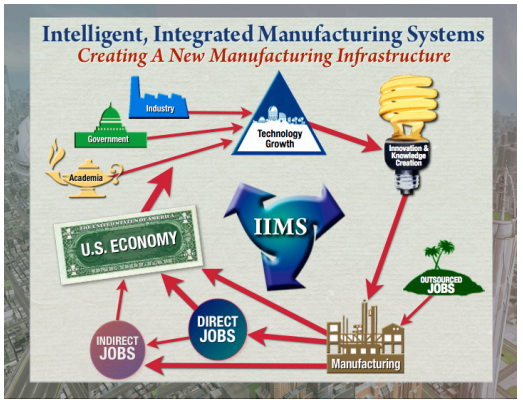


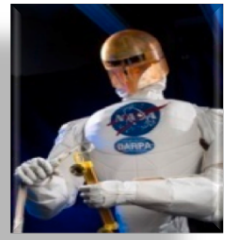


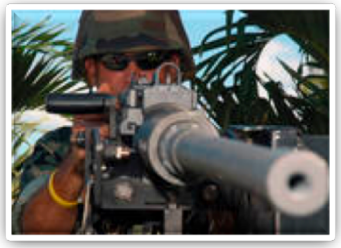
Leverage OGA Capabilities

- **President's Task Force on Space Workforce and Economic Development –** Space Coast Regional Innovative Cluster (EDA, Space Florida)
  - Proposal to establish Interagency Supply Chain and Regional Manufacturing Industrial Clusters
  - Short-term: Triage for failing product lines and Job creator
  - Long-term: Critical Technology center of excellence and economic growth
- **Interoperable Supply Chains** – A pilot study to determine the feasibility to share DoD and NASA supply chains to reduce costs and risk
  - Army suppliers produced Robonaut 2 hardware
  - NASA suppliers produced machine gun barrel extensions
- **Department of Commerce Survey** – Using DoC Bureau of Industry and Security's expertise in assessing the industrial base (IB) to conduct a space IB health survey.
  - Survey released in 6/10, report expected 12/10
- **Supply Chain Mapping** – Using MDA developed software to collaborate on mapping the space supply chain
  - Initial mapping of supplier overlap (NASA, MDA, USAF)

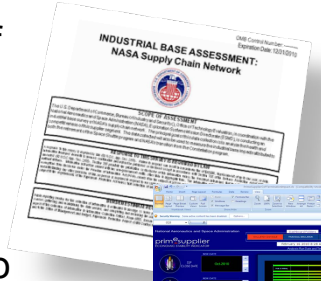


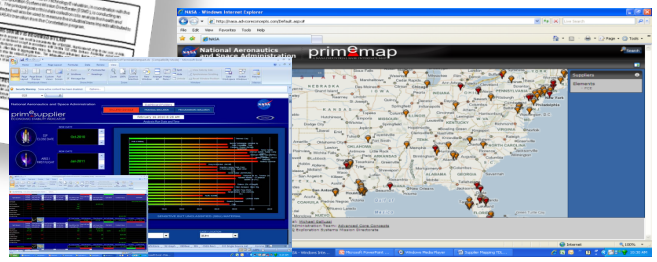






DoD / NASA Network of Manufacturers

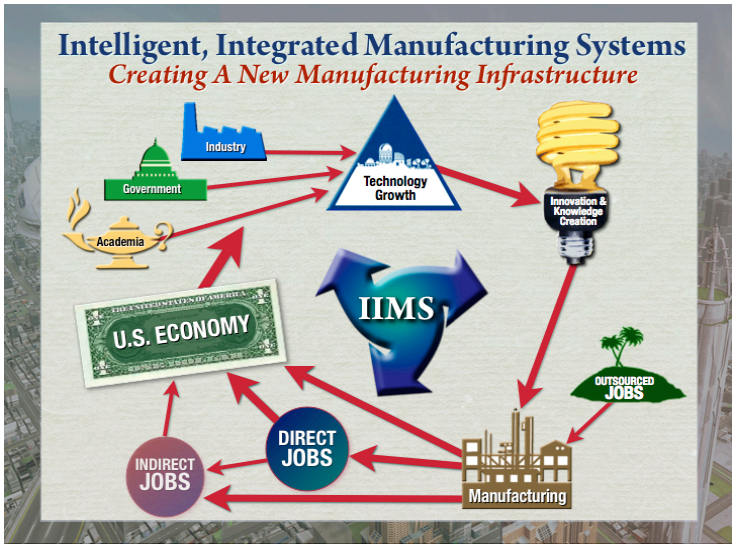


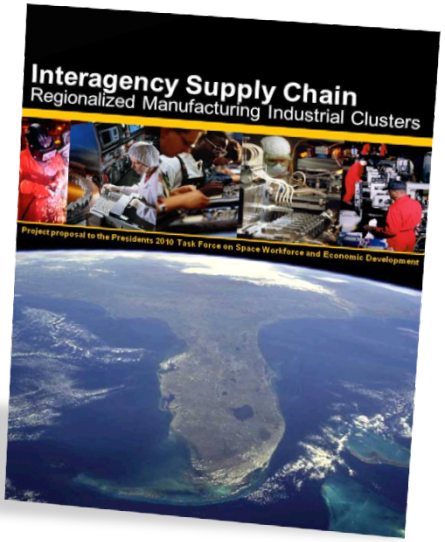


Supplier Mapping Software

Leverage OGA Capabilities (DoC, Space Florida)

- **President's Task Force on Space Workforce and Economic Development –** Space Coast Regional Innovative Cluster (Economic Development Administration, Space Florida)
  - Intelligent, Integrated Manufacturing adjusts to changing customer demands
    - Upside/downside supply chain flexibility
  - Secure Service Oriented Architecture through Industry Standards for Information Technology delivery and Product Data Management collaboration
  - Coherency of physical and virtual supplier relationships as well as corporate and government relationships
  - Hardware Demand Aggregation to ensure a viable industrial base and product offering





Leverage OGA Capabilities (Army)

Interoperable Supply Chains – A pilot study to determine the feasibility to share DoD and NASA supply chains to aggregate hardware demand, reduce costs and risk with an emphasis on manufacturing.

Study Results:

"The results to date indicate an excellent probability of success for NASA and the DoD to have interoperable supply chains. This will not come without concerted effort and patience as suppliers go through their learning curves. This can be significantly reduced by sharing the results of this demonstration."

Interoperability Issues:

- **NASA has higher business process, configuration & traceability requirements than DoD**
- **NASA document of record is the 3-D model with drawings provided as reference whereas DoD is 2D**
- **NASA cleaning requirements down to the microbe and radiation hardening requirements**

NASA Ratio to DoD Suppliers	Barrel	Shank
Effort*		
Sourcing	196%	27%
Engineering	-28%	135%
Manufacturing	-71%	-82%
Total	-44%	-43%

* - means NASA had less effort, + means NASA had more effort

Supplier Mapping Software

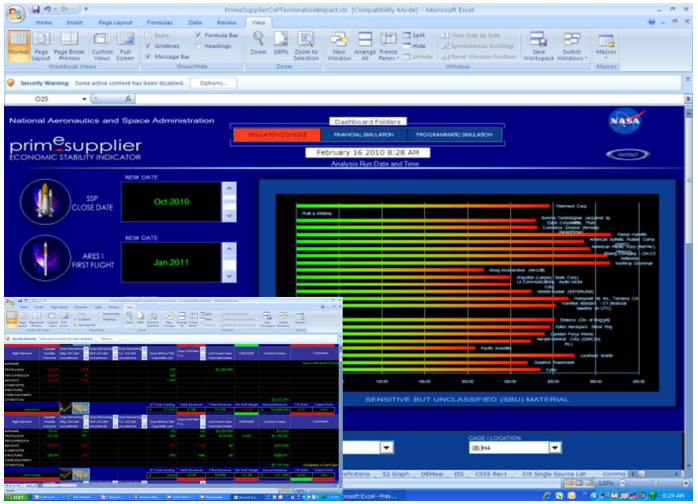
Leverage OGA Capabilities (Missile Defense Agency)

Supply Chain Mapping – Using Missile Defense Agency developed software to map the NASA Human Space Flight supply chain

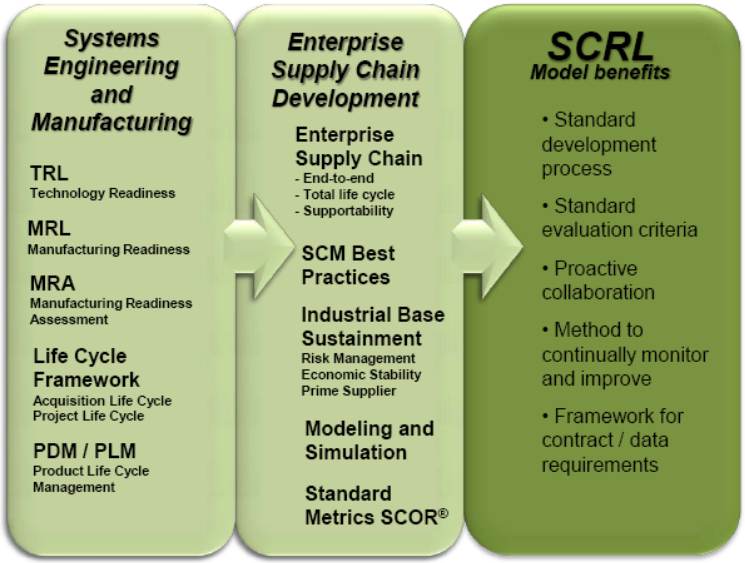
- Initial mapping of supplier overlap (NASA, MDA, USAF)
- Identification of common single source suppliers

Current activity

- Recommendation made to Space Industrial Base Council to create common government space supplier map.
  - Interest by NRO and AF to adopt MDA and NASA supply chain software
  - Working together on common mapping definitions
  - Plan to use DoC survey data to add to supplier data
- Supplier economic modeling and simulation (PrimeSupplier)
  - DoD ManTech Program funding development
- Supply Chain Readiness Level (SCRL) Development
  - Have discussed with OGAs making SCRL a standard



http://www.fuentek.com/technologies/Primesupplier.htm



Summary

- **Partnerships are an important component of ESMD's exploration program**
  - Minimize costs
  - Maximize efficiency and innovation of future human space exploration missions
- **ESMD is engaging and leading internationally**
  - Multi-laterally to coordinate exploration plans through ISECG
    - The GPOD is an important example of the benefits of international partnerships
    - The Global Exploration Roadmap is an important future product to coordinate global space plans
  - Bi-laterally to create partnerships where mutually beneficial
- **ESMD is engaging and leading within the government**
  - Actively engaged with other government agencies to leverage their capabilities and infrastructure
    - Commerce Dept, Army, Missile Defense Agency, Space Florida, etc